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Case Report

Case Report: The Microwave Syndrome after Installation of 5G Emphasizes the Need for Protection from Radiofrequency Radiation

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Abstract

In this case, report two previously healthy persons, a man aged 63 years and a woman aged 62 years, developed symptoms of the microwave syndrome after installation of a 5G base station for wireless communication on the roof above their apartment. A base station for previous telecommunication generation technology (3G/4G) was present at the same spot since several years. Very high radiofrequency (RF) radiation with maximum (highest measured peak value) levels of 354 000, 1 690 000, and >2 500 000 μW/m^2 were measured at three occasions in the bedroom located only 5 meters below the new 5G base station, compared to maximum (peak) 9 000 μW/m^2 prior to the 5G deployment. The rapidly emerging symptoms after the 5G deployment were typical for the microwave syndrome with e.g., neurological symptoms, tinnitus, fatigue, insomnia, emotional distress, skin disorders, and blood pressure variability. The symptoms were more pronounced in the woman. Due to the severity of symptoms, the couple left their dwelling and moved to a small office room with maximum (peak) RF radiation 3 500 μW/m^2. Within a couple of days, most of their symptoms alleviated or disappeared completely. This medical history can be regarded as a classic provocation test. The RF radiation levels in the apartment were well below the limit proposed to be "safe" below which no health effects would occur, recommended by the International Commission on Non-Ionizing Radiation (ICNIRP). These now presented symptoms of the microwave syndrome were caused by non-thermal effects from RF radiation and highlight that the ICNIRP guidelines used in most countries including Sweden do not protect human health. Guidelines based on all biological negative effects from RF radiation are urgently needed, as well as monitoring human health, not the least due to rapidly increasing levels of exposure.

Keywords: Base station; 5G; Radiofrequency radiation; Electromagnetic hypersensitivity; Microwave syndrome; Health

Introduction

In recent years, human exposure to pulse-modulated microwave radiation [also called radiofrequency (RF) radiation] from wireless technology has increased exponentially. Microwaves are frequencies in the range of 300 MHz to 300 GHz within the radiofrequency (RF) spectrum [1]. The increase is mainly a result of the expansion of 4G+ and 5G as well as an increased amount of consumer products based on technologies that emit microwave radiation.

In parallel with this exploding RF radiation exposure, regulations and so-called safety limits applicable to the permitted RF radiation in most countries are based on a severely outdated approach from the 1950s. These 'safety" limits (or guidelines) only protect people against harmful effects that occur as a result of acute heating, also called thermal effects. These occur when

RF radiation is extremely high thereby causing an increase in tissue temperature of more than 1 °C within a very short time. The guidelines based on thermal effects also ignore the effects of particular characteristics of the exposure as the modulation and/or pulsation or simultaneous exposure to various signals. In consequence, humans are completely unprotected against a whole range of harmful effects that are caused by non-thermal RF radiation. These include cancer, DNA damage, oxidative stress, neurological, and other biological effects that may impair human health. Scientific research has repeatedly and abundantly shown such effects to occur at levels well below the thermal based limits [2-6]. In addition current guidelines for exposure to RF radiation give no protection against harmful effects on biodiversity, i.e., the variety of living species on Earth, including plants, animals, bacteria, and fungi.

Scientists have called for considerably lower maximum allowed limits for the prevention of human health. The BioInitative Report suggested already in 2012 a limit of 30-60 μW/m^2, and yet lower for sensitive persons and children, 3-6 μW/m^2 [2]. The EUROPAEM EMF guidelines proposed in 2016 maximum exposure to be 10-1 000 μW/m^2, and lower at nighttime 1-100 μW/m^2, and yet lower for sensitive persons 0.1-10 μW/m^2 [7]. Comparison of guidelines proposed by different organizations are presented in Table 1. Hundreds of scientists and organizations have called for a revision of the limits for better protection of humans and the environment (www.5gappeal.eu; www.emfcall.org; www.emfscientist.org).

Year	Power Density (μW/m^2)	Name	Description
1998	10 000 000	ICNIRP 1998 [15] Whole body exposure averaged over 6 min	10 000 000 for 2–300 GHz
	9 000 000		9 000 000 for 1800 MHz
	4 500 000		4 500 000 for 900 MHz
2001	1 000	Salzburg Resolution [52]	1 000 for the sum total of all pulse modulated high-frequency exposures 100 000 for the total of all high-frequency irradiation. [1]
	100 000		
2001	100	EU Parliament STOA 2001 [53]	For chronic exposure from pulsed microwaves.[1]
2002	1	New Salzburg Precautionary Exposure Limit Indoor [54]	Indoor chronic exposure from GSM base stations.[1]
2012	3-6	Bioinitiative 2012 Recommendation [2]	For chronic exposure to pulsed RF.[1]
2016	0.1-100	EUROPAEM EMF Guidelines [7]	For extended exposure at least 4 hours a day to frequencies between GSM 900 to WiFi 5.6 GHz depending on sensitivity, night time or daytime exposure. Peak maximum values.
2020	10 000 000	ICNIRP 2020 [16] Whole body exposure averaged over 30 min	10 000 000 for >2–300 GHz
	9 000 000		9 000 000 for 1800 MHz
	4 500 000		4 500 000 for 900 MHz

2020	10 000 000	ICNIRP 2020 [16] Local exposure averaged over 6 min	10 000 000 for 400 MHz
	18 200 000		18 200 000 for 800 MHz
	36 600 000		36 600 000 for 1 800 MHz
	40 000 000		40 000 000 for 2 GHz
	40 000 000		40 000 000 for 6 GHz
	26 600 000		26 600 000 for 60 GHz
	20 000 000		20 000 000 for 300 GHz
[1]Average or peak maximum values not specified.			

Table 1: Guidelines on recommended limit exposure levels for the public by different organizations for microwave radiation in $\mu W/m^2$.

Microwave sickness or illness resulting from microwave exposure at non-thermal levels, was described already in the 1960's and 1970's in the East European countries [8]. The RF radiation was considered to mainly affect neural, cardiovascular, and endocrine functions. Investigations of workers showed than microwave or RF exposure at non–thermal levels caused symptoms such as fatigue, dizziness, headache, sleep disorders, anxiety, problems with attention and memory. These symptoms were attributed to occupational exposure [9]. In a review of Soviet and Eastern European scientific papers, including studies on animals, it was concluded "*a surprisingly wide variety of neurological and physiological reactions are to be expected*" because of exposure to non-thermal levels of RF radiation [10].

Other terms for the illness were radiofrequency sickness syndrome [11] or microwave syndrome [12]. Research observed that the symptoms in general declined after the exposure had ceased [9, 13]. Thus, Marha et al noted that "*at a certain time after exposure had ended (sometimes as long as several weeks or more) (page 31), the organism usually returns to its original physiological state and all subjective and objective complaints vanish*" [9]. It was noted that non-thermal effects depended primarily on the modulation and/or pulsation of the signal. The effects depended on both the peak and average intensity of the RF radiation. Pulsed signals and simultaneous exposure to several frequencies were found to produce more effects and were thus more hazardous. The effects increased with time of exposure [9, 14].

Fifty years ago Eastern European maximum permissible limits were based on the recognition of non-thermal effects and were very much lower than the whole body limits of 10 000 000 $\mu W/m^2$ (averaged) applied in most western countries today and recommended by the International Commission on Non-Ionizing Radiation in 1998, (ICNIRP) [15] and later recommended to be averaged over 30 minutes in 2020 [16]. The guideline for local exposure averaged over 6 minutes is 40 000 000 $\mu W/m^2$ in ICNIRP 2020 for certain frequencies, i.e. those currently used for 5G [16], see Table 1 in the publication. Eastern European limits were 100 000 $\mu W/m^2$ for continuous daily microwave public exposure [17]. In former Czechoslovakia yet even lower limits were applied for pulsed microwave radiation [14].

In recent decades, the microwave syndrome is also referred to as "electromagnetic hypersensitivity (EHS)" in the international literature [8]. Individuals suffering from EHS can react with health symptoms already at very low exposure levels [18]. The sensitivity to RF radiation varies between different persons [19]. Today the microwave syndrome is caused by microwave radiation emitted from mobile phones, base stations for wireless communication, WiFi, electric "smart" meters etc. Mostly the symptoms originate from the central nervous system and the heart, but other organs such as the skin and the hormone system are often also affected. The symptoms correspond to those described 50 years ago in studies of occupational exposure and include sleeping problems, headache, heart palpitations, balance disorders and mood swings. There is a whole range of symptoms that vary between affected persons [4]. RF radiation is not visible and does not smell. Thus, it is not easy to identify exposure using the sensory organs and attribute RF exposure to the various symptoms.

Several studies during the 21st century have shown increased risk for the microwave syndrome symptoms among those living close to base stations, although highest exposure levels were far below the limits recommended by ICNIRP [20]. For example a study from Spain reported exposure from base station associated with increased prevalence of fatigue, irritability, headaches, nausea, loss of appetite, sleeping disorder, depressive tendency, and feeling of discomfort, difficulty in concentration, loss of memory, visual disorder, dizziness and cardiovascular problems although the highest exposure group was exposed to only between 165 to 4 400 $\mu W/m^2$ in the bedroom [21].

A study from Austria [22] reported that headaches, cold hands or feet, difficulties in concentrating, tremor, loss of appetite,

and feelings of exhaustion increased with increasing exposure to RF radiation from mobile phone masts. The highest exposure group in the study was exposed to between 500 to 4100 μW/m^2 in the bedroom.

A study from Germany [23] found a significant correlation between measured RF radiation from mobile phone base stations and insomnia, depressions, cerebral symptoms, joint illnesses, infections, skin changes, heart and circulation disorders, and disorders of the optical and acoustic sensory systems, and the gastro-intestinal tract. The most exposed group was exposed on average to 3 631 μW/m^2 (1.17 V/m) in the bedroom.

Another German study examined the effects of a new mobile phone base station on the stress hormones adrenaline and noradrenaline, dopamine, and PEA (phenylethylamine) as well as some symptoms among 60 individuals in a small village. Urine samples from the participants were analyzed during one and a half year. RF radiation levels were measured outside the residences of each participant and the average peak value was only 76.9 μW/m^2 among all participants with the highest measured value at one participant's home at 320 μW/m^2. The number of participants with sleep problems, headache, allergy, concentration problems and dizziness increased after the activation of the GSM base station. Also adrenaline and noradrenaline levels increased during the first six months but were restored to initial levels after 18 months. Dopamine levels on the other hand decreased after the activation while the PEA levels decreased six months later and continued to decrease over the study period [24].

Further, a study from India [25] found increased frequency of micronuclei and lipid peroxidation in cultured human peripheral blood lymphocytes of people living within 80 meters from mobile phone base stations, compared to a control group living at a minimum distance of 300 meters away. The analysis of various antioxidants in the plasma revealed a significant reduction in glutathione concentration and catalase and superoxide dismutase activities. Measurements showed highest exposure between 2 800 and 7 520 μW/m^2 from the base station in the bedroom.

Other studies have investigated various microwave syndrome symptoms in relation to distance from base stations. Increased prevalence has been found within 500 meters [20, 26].

A study from India reported increased incidence of sleeping problems, headache, dizziness, irritability, concentration problems and increased blood pressure among individuals living in proximity to base stations [27].

Some previous studies have proposed that these symptoms related to microwave exposure from mobile phone base stations are the effect of people's anxiety, concerns or worries over the possible impact on their health from the base stations. A recent study from France, with that aspect in focus [28], reported that exposure from mobile phone base stations was not related to self-reported non-specific or insomnia-like symptoms among the 354 individuals investigated. However an association between exposure and insomnia-like symptoms "*for people with environmental concerns*" was reported. Exposure varied between 2.38 μW/m^2 (0.03 V/m) to 33 995.76 μW/m^2 (3.58 V/m) in the bedroom of each participant. Multiple linear and logistic regression was performed for the assessment. The results were based on low participation rate (13 %) for the study in which home exposure measurements were performed.

Provocation studies have often yielded mixed results without unequivocal evidence on the existence of microwave syndrome or EHS. Instead, psychological problems have been postulated to cause the manifestation of the symptoms. However, most investigations have inherent methodological limitations that make the results difficult to evaluate or even erroneous, see discussion in [29].

Animal studies have in great numbers confirmed neurological and behavioral effects of microwave radiation from modern wireless technologies [30-32]. As an example, exposure to 2.45 GHz microwave radiation caused reduced learning and memory as well as expression of anxiety in rats. Exposure caused oxidative stress and reduced level of antioxidants in the brain [33]. A summary of recent literature on neurological effects of RF radiation showed that a majority of animal studies reported effects [32].

Hypothesis

No studies have yet investigated effects of radiation from 5G base stations on human health. Therefore a real life provocation study would be most valuable. We hypothesize that 5G will increase exposure to microwaves and that the radiation may cause illness described as microwave syndrome or microwave sickness.

Methods/Case history

We studied two persons, a couple, man aged 63 years and woman aged 62 years that had lived in the same apartment in a Swedish city for 10 years. The apartment was located at the top 7th floor of the building, Figure 1. Until the 5G deployment they were both rather healthy. On November 4, 2021 measurements were made of RF radiation in their apartment, i.e., before the 5G deployment which took place a couple of weeks later. The measurement was initiated by the couple as they were informed that new base station antennas for 5G were to be installed on the roof above their apartment. A base station for previous telecommunication generations (3G and 4G) was operating at the same spot already when they moved into the apartment. The couple left their apartment for another dwelling, which was the man's office room, a few days after the deployment of the new 5G antennas. A couple of weeks later, on December 15th, 2021 the first

measurement of the RF radiation from the new 5G base station was made in the bedroom of their apartment, located just below the new 5G antenna as well as in the office room where the man and the woman had moved. Additional measurements in the apartment were made on February 2 and March 18, 2022 and in April in the house on the countryside where they moved in March 2022.

All measurements were made daytime with the device Safe and Pro II with a true response detection range between 400 MHz and 7.2 GHz. It was calibrated by the manufacturer and has an accuracy of ±6 dB. (https://safelivingtechnologies.com/products/safe-and-sound-pro-ii-rf-meter.html). In Sweden in city environments, the frequencies around 3.5 GHz and below are most commonly used for 5G, i.e., frequencies covered by the exposimeter.

The man and the woman were asked to evaluate prevalence and severity of microwave syndrome symptoms experienced in the different exposure situations. The list of symptoms is adapted after Belpomme 2015 [34].

Figure 1: Top floor apartment adjacent to base stations. Two bedrooms close to the base station antennas, which are attached to the chimney.

Results

In Table 2 the measurement results, all in μW/m^2, before and after addition of 5G on the roof of their apartment, in the office room that they moved to, and further in the house to which they later moved in 2022, are presented.

The RF radiation was relatively high before the 5G deployment, maximum (highest measured peak value) 9 000 μW/m^2, but increased with 5G to a maximum (peak) level of 354 000 measured on December 15, 2021 and later maximum (peak) 1 690 000 μW/m^2 on February 2, 2022, measured above the head of one of the beds. Yet another measurement on March 18, 2022, showed a maximum (peak) level of >2 500 000 μW/m^2 in the bedroom at the same place as for the February 2, 2022 measurement, which is the maximum level that the used meter can display. This increase over time may indicate increasing use of 5G after the installation. The other dwelling, the office room, to which they moved had much lower RF radiation, maximum (peak) 3 500 μW/m^2 close to the bed. In the house on the countryside, where they later moved in March 2022, maximum (peak) level was measured to 33 μW/m^2 in the bedroom, Table 2.

Table 3 shows the rating of symptoms by the man at two occasions in the apartment; before and with 5G, in the office room with much lower exposure, and finally in a house on the countryside where they moved in March 2022 with even lower exposure. Stronger exposure underneath the 5G antenna caused him mostly fatigue, tinnitus, headache, blood pressure disorder, skin problems and nose bleeding. As displayed in Table 3 his health improved soon after leaving the high RF radiation apartment. Still he has some arthralgia (joint pain) that seems not to be related to his RF exposure.

In Table 4 the symptoms for the woman are presented. She developed symptoms typical for the microwave syndrome, but to a higher degree than her husband. Most severe were insomnia and dizziness followed by skin disorders, concentration problems, irritability, balance problems, short-term memory deficiency, confusion, tiredness, depression tendency and symptoms from the heart and lungs. Most of these problems disappeared completely or were substantially reduced within days after movement to the dwelling with much lower RF radiation. The woman's severe insomnia completely disappeared for instance.

Place	Apartment with 4G/3G before 5G[1]	Apartment after 5G deployment[2]	Apartment after 5G deployment[3]	Apartment after 5G deployment[4]	Office space where the couple moved to[5]	New home countryside[6]
Bedroom	9 000 (NA)	354 000 (NA)	1 690 000 (5 000-20 000)	> 2 500 000 (9 000-50 000)	3 500 (20-105)	33 (2-6)
Living room	2 000 (NA)	51 000 (NA)	222 000 (1 400-3 500)	183 000 (500-5 200)	NA	300 (2-6)
Hall	3 000 (NA)	154 000 (NA)	269 000 (500-3 500)	342 000 (400-10 100)	NA	NA

Table 2: Levels of maximum (peak) microwave radiation in apartment before 5G, with 5G, in office space and present home on countryside. Measured average levels over 2-5 min. in brackets ($\mu W/m^2$).

NA= Not available.

[1] Measurement made on November 4, 2021

[2] Measurement made on December 15, 2021

[3] Measurement made on February 2, 2022

[4] Measurement made on March 18, 2022

[5] Measurement made on February 4, 2022

[6] Measurement made on April 8, 2022

Symptom	Before 5G November 2021	With 5G November 2021	After 5G (office space) January, 2022	After 5G (house countryside) March 2022
Headache	0	6	0	0
Dysesthesia	0	0	0	0
Myalgia	0	0	0	0
Arthralgia	3	3	3	4
Ear heat/otalgia	0	0	0	0
Tinnitus	2	6	2	3
Hyperacousis	0	0	0	0
Dizziness	0	0	0	0
Balance disorder	0	0	0	0
Concentration/Attention deficiency	0	0	0	0
Loss of immediate memory	0	0	0	0
Confusion	0	0	0	0
Fatigue	0	7	0	0
Insomnia	0	5	0	0
Depression tendency	0	3	0	0
Suicidal ideation	0	0	0	0
Transitory cardiovascular abnormalities, heart rate variability	0	0	0	0
Occular deficiency	0	0	0	0
Anxiety/Panic	0	0	0	0
Emotive	0	3	0	0

Irritability	0	0	0	0
Global body dysthermia	0	0	0	0
Lungs; dyspnoea, cough,	0	0	0	0
Stomach, diarrehea (involuntary)	0	0	0	0
Skin (face, arms, legs)	2	5	4	1
burning, lancinating skin on hands and arms	0	0	0	0
Nose bleeding	1	5	1	0
Blood pressure variability (high, low)	1	5	1	0
Hair loss	0	0	0	0

Table 3: Clinical symptoms grades 0-10. 0 = no symptoms, 1 = mild symptoms, 10 = unbearable pain and/or discomfort. Previously healthy man aged 63 years.

Symptom	**Before 5G November, 2021**	**With 5G, November, 2021**	**After 5G (office space) January, 2022**	**After 5G (house countryside) March, 2022**
Headache	0	6	1	0
Dysesthesia	0	2	0	0
Myalgia	0	0	0	0
Arthralgia	0	2	1	0
Ear heat/otalgia	0	1	0	0
Tinnitus	2	6	3	1
Hyperacousis	0	2	0	0
Dizziness	2	10	3	1
Balance disorder	0	7	2	1
Concentration/Attention deficiency	1	8	1	1
Loss of immediate memory	0	7	2	1
Confusion	0	0	0	0
Fatigue	2	8	2	0
Insomnia	0	10	0	0
Depression tendency	0	6	0	0
Suicidal ideation	0	0	0	0
Transitory cardiovascular abnormalities, heart rate variability	1	5	1	0
Occular deficiency	1	4	1	1
Anxiety/Panic	0	3	0	0
Emotive	0	7	1	0
Irritability	0	8	2	0
Global body dysthermia	0	7	1	0
Lungs; dyspnoea, cough,	2	7	2	0
Stomach, diarrehea (involuntary)	0	0	0	0

Skin (face, arms, legs)	0	0	0	0
burning, lancinating skin on hands and arms	0	8	0	0
Nose bleeding	0	0	0	0
Blood pressure variability (high, low)	0	5	0	0
Hair loss	0	0	0	0

Table 4: Clinical symptoms grades 0-10. 0 = no symptoms, 1 = mild symptoms, 10 = unbearable pain and/or discomfort. Previously healthy woman aged 62 years.

Discussion

The experienced symptoms after the deployment of 5G are typical for the microwave syndrome affecting primarily the nervous and cardiovascular system,

This survey may be regarded as a classic provocation study. Measurements of microwave radiation were made before installation of 5G, after the installation and in the new accommodations. Both persons responded to questions on symptoms at these four different exposure situations. This investigation shows an association between very high exposure to microwave radiation from 5G and the symptoms attributed to the microwave syndrome. The symptoms were experienced shortly after the installation of 5G base stations on the roof close to their apartment. Very high RF radiation in the bedroom of the apartment only five meters below the 5G base station was later measured. The roof was covered by roofing felt only, which might have contributed to the very high levels of maximum microwave radiation due to limited shielding effect. Plate or copper roof would most likely have reduced the levels. Considerable health improvement occurred after movement to dwellings with much lower microwave radiation. It should be noted that dosimeter and spectrum analyzer measurements would be needed to get a full picture of RF radiation exposure in high-risk apartments.

This survey confirms previous studies that found increased prevalence of similar symptoms among people living close to mobile phone base stations exposed to microwave radiation. However previous studies reported increased prevalence at much lower intensities.

The couple experienced severe symptoms shortly after the deployment of the 5G before they had knowledge of the sharp increase of RF radiation after the deployment of the 5G base station. Also the couple had lived with a base station for previous telecommunication generations at the very same place for several years without experiencing serious negative health effects. This argues against the hypothesis made by some scientists, as well as the telecommunications industry, that these symptoms near base stations are caused by worries or concern. It is also hard to explain how all these symptoms, including nose bleeding, tinnitus, skin disorders, severe insomnia and headache could be provoked because of concern.

In a re-analysis of an earlier Spanish study on the microwave syndrome and 2G base stations, the authors concluded that several symptoms were independent of the individuals' worries about being irradiated [21].

The current prevalence of the microwave syndrome or EHS in Sweden is not known. It has not been investigated. It can however be assumed that the prevalence has increased due to increasing exposure to RF/microwave radiation after the implementation of 4G and 5G. No doubt, the use of wireless technology for communication has increased substantially during the last two decades. Measurements carried out in Stockholm in 2019 near mobile phone base station antenna array showed maximum reading of 2 648 000 $\mu W/m^2$ and average maximum level (over 1 minute) of 388 000 $\mu W/m^2$ [35].

In Columbia, USA, high RF radiation from 5G low positioned base stations was reported [36]. These are levels that far exceed levels that have been shown to cause harmful effects on human health and the levels measured around base stations during the first ten years of this millennium. To our knowledge, no studies have until now shown that full body exposure to these levels, nor from previous 2G, 3G, 4G or from 5G, are safe for human health.

This study illustrates that 5G leads to a huge increase in microwave exposure. Already before the roll out of 5G, scientists and medical doctors called for a moratorium on the 5G deployment due to the "*massive increase of mandatory exposure*" to microwaves and the fact that the health hazards have not been investigated (www.5gappeal.eu). Also in a presentation at the ITU Workshop on 5G, EMF & Health Warsaw, December 5, 2017, Christer Törnevik from Ericsson, one of the major 5G technology stakeholders, showed that 5G will lead to a substantial increase in RF radiation exposure [37]. If 100 times lower limits than ICNIRP's were to be used, i.e., those applied in some countries, 5G roll out would be a "*major problem or impossible*". Exclusion zone could be 35 meters below a base station on the roof of a building in cities. This case is clearly within that exclusion zone.

In 2011, the Parliamentary Assembly of the Council of Europe recommended that member states should aim to generally

keep the microwave radiation levels in society as low as possible, as well as strive for lower safety limits for permissible RF radiation to 100 μW/m^2. Children and other vulnerable groups should be particularly protected. Governments were also urged to ensure that the public is widely informed about the known risks [38].

Also in 2011 IARC classified RF radiation as a 'possible human carcinogen' Group 2B [39, 40]. Research has shown increased risk of tumours in the brain and the auditory nerve among people with use of cordless/cellular phones. This decision, which was based on the evaluation of all research in the field up until 2011, has not led to the reduction of public exposure. On the contrary, the exposure has increased substantially [35, 36].

During recent years, a Swiss government expert group has concluded that the majority of research shows that RF radiation causes oxidative stress, which when occurring over time may lead to various diseases [5]. A research inquiry under the European Parliament has found that RF radiation from 5G and other wireless technologies can cause cancer, and that this RF radiation damages men's fertility and possibly also women's reproductive ability [41]. An investigation by The National Academies of Sciences in the USA [42] concluded that directed pulsed RF radiation "*appears to be the most plausible*" cause of a large number of diplomats' ill health and correspond to the symptoms that have been reported during 50 years as a result of exposure to RF radiation (similar to the microwave syndrome).

The updated BioInitiative Report [43] concluded that [44]: "*When the cumulative body of evidence is assessed, the overall picture on low-intensity nonthermal levels of RFR [radiofrequency radiation] shows a clear and consistent pattern of adverse effects that form the basis of the mechanisms whereby RFR can cause the cancers seen in human populations. Of 261 studies looking at oxidative effects from RFR exposure, 240 (91%) showed damage. Of 346 studies on effects of RFR on genes, 224 (65%) reported genetic damage. Oxidative stress and genetic damage are the major mechanisms leading to cancer. In addition, RFR exposure causes effects on brain and behavior. Of 336 studies published on RFR neurological effects, 73% reported effects, and only 27% showed no effect."*

The current limits based on thermal effects from ICNIRP [16] and FCC [45] are severely insufficient and outdated and do not protect against known health risks. They offer no safety. On the contrary, they allow exposure to RF radiation at levels that have repeatedly been shown to be harmful [46]. This case study clearly demonstrates typical microwave syndrome symptoms that occurred rapidly at maximum levels well below the ICNIRP limits that allow whole body exposure to be as high as 10 000 000 μW/m^2 averaged over 6 minutes following ICNIRP 1998 [15] and averaged over 30 minutes as recommended by ICNIRP 2020 [16]. This even allows for short time pulses or maximum values to be much higher than the average value over 6 or 30 minutes, up to 1000 times higher [47].

The EMF Scientist Appeal was launched in 2015 (www.emfscientist.org), and is today signed by 256 scientists, all active in this field of research. They demand that people must be better protected against risks from this form of RF radiation exposure by more stringent guidelines for permitted RF radiation and that the general public and the medical profession, particularly doctors, should be informed about the risks.

A 2018 joint letter for better protection against harmful effects of microwave radiation, the EMF Call, signed by 164 scientists and medical doctors together with 95 non-governmental organizations concluded that ICNIRP's limits "*are not protective, rather they pose a serious risk to human health and the environment since they allow harmful exposure to the population, including the most vulnerable*." [48].

This case history underscores the necessity to reduce human and environmental RF radiation exposure based on unbiased risk evaluation by scientists with no conflicts of interest in terms of ties to the telecom industry. ICNIRP and the WHO project that collaborates and recommends the ICNIRP limits have been shown to have such ties to the industry [47].

The ongoing massive increase in human exposure to microwave radiation from wireless technology is expected to lead to serious consequences in the form of deteriorating public health and harmful effects on plants, insects, birds and other animals. Research shows increasing and clear evidence that this RF radiation is harmful both to humans and to other biological life at levels that are far below the ICNIRP limits approved by many countries [49].

To our knowledge, there is no study that shows that these levels, or the maximum levels allowed by applying the ICNIRP guidelines, are safe for long-term exposure to RF radiation from base stations for 5G, 4G, 3G or even 2G. No studies have examined whole body long-term exposure effects at ICNIRP limits or at maximum levels measured in this study.

As mentioned before, in 2017, the 5G Appeal was launched (www.5gappeal.eu). The appeal, which is currently signed by more than 400 medical doctors and scientists from around the world, demands that decision-makers stop the 5G expansion "*until potential hazards for human health and the environment have been fully investigated by scientists independent from industry"*, due to the risk of serious consequences for human health [50], as discussed further in [51-54].

Obviously, the microwave syndrome is not a psychological complaint and must together with EHS be regarded as an established diagnosis by the medical society. The patients should be treated with respect, examined, get a medical diagnosis, and

treatment. Elimination or considerable reduction of exposure to microwave radiation would be the first step. All measures must be taken at an early stage of the microwave syndrome/EHS in order to reduce the risk for irreversible harm and chronic illness such as cancer or neurological diseases. The vast majority, including health care staff, are unaware and uninformed about this syndrome and other risks to health due to this exposure. Education, not the least of medical doctors, is urgently necessary. The microwave syndrome and EHS need to be defined with an ICD-10 code so as also to monitor the prevalence in the society.

Conclusions

5G is being rolled out without any studies showing that 5G is safe for humans and wildlife.

To our knowledge, this is the first study of health outcomes in persons exposed to 5G RF radiation. Within a couple of days, a new 5G base station caused severe symptoms in two previously healthy persons that correspond to the microwave syndrome. The deployment of 5G also caused a dramatic increase in maximum (peak) microwave radiation exposure, from 9 000 $\mu W/m^2$ to >2 500 000$\mu W/m^2$. The symptoms quickly reversed when the couple moved to a dwelling with much lower exposure. This case is in line with scientific findings reported already 50 years ago on effects of exposure to microwave radiation and that most symptoms disappear when the exposure is discontinued. This study and previous studies show that the microwave syndrome appears at levels well below the current limits recommended by the ICNIRP.

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Availability of data and materials

The information generated and analyzed during the current study is available from the corresponding author on reasonable request.

Authors' contributions

Authors both participated in the conception, design and writing of the manuscript, and have read and approved the final version

Ethics approval and consent to participate

Not applicable.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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